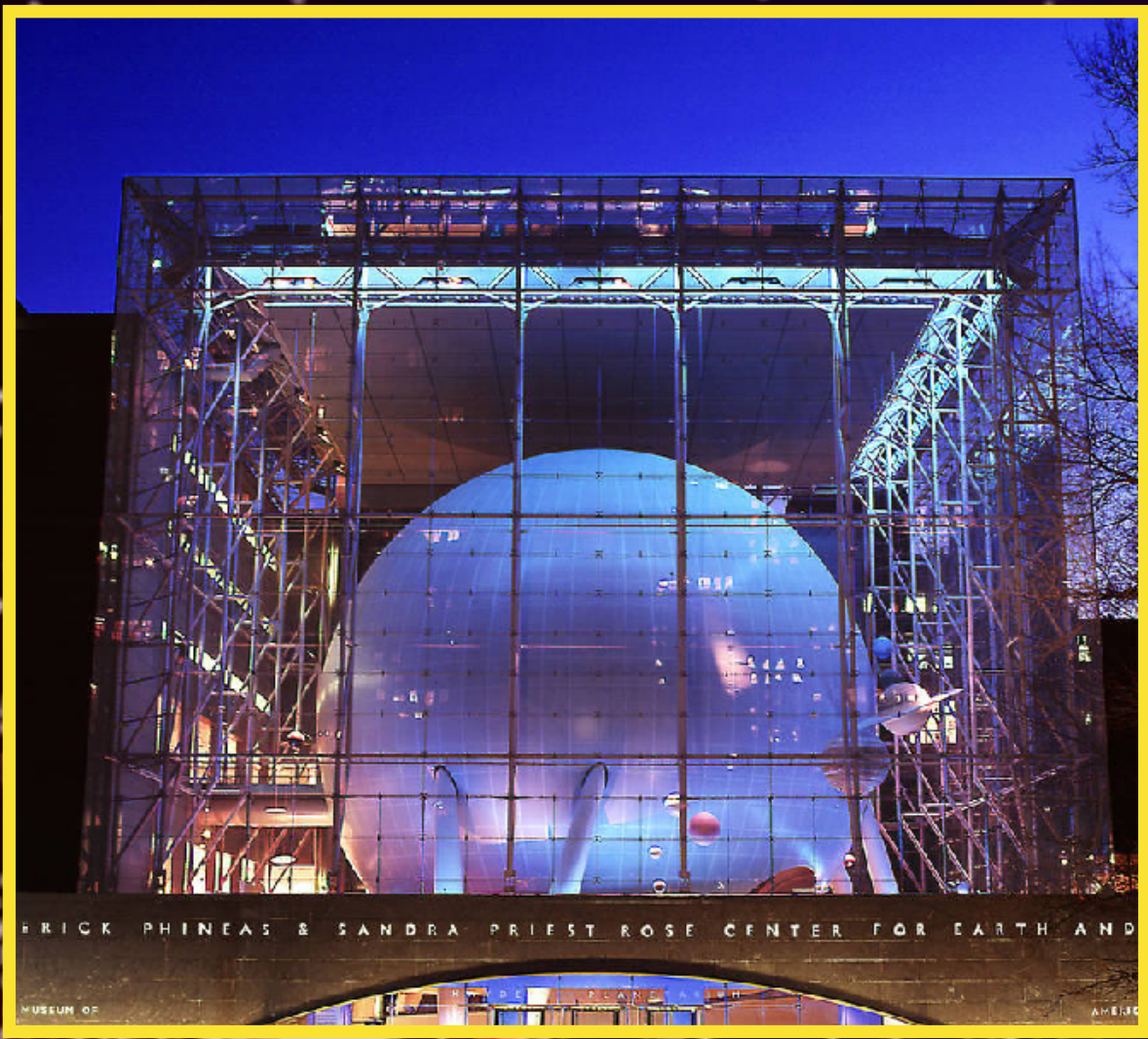
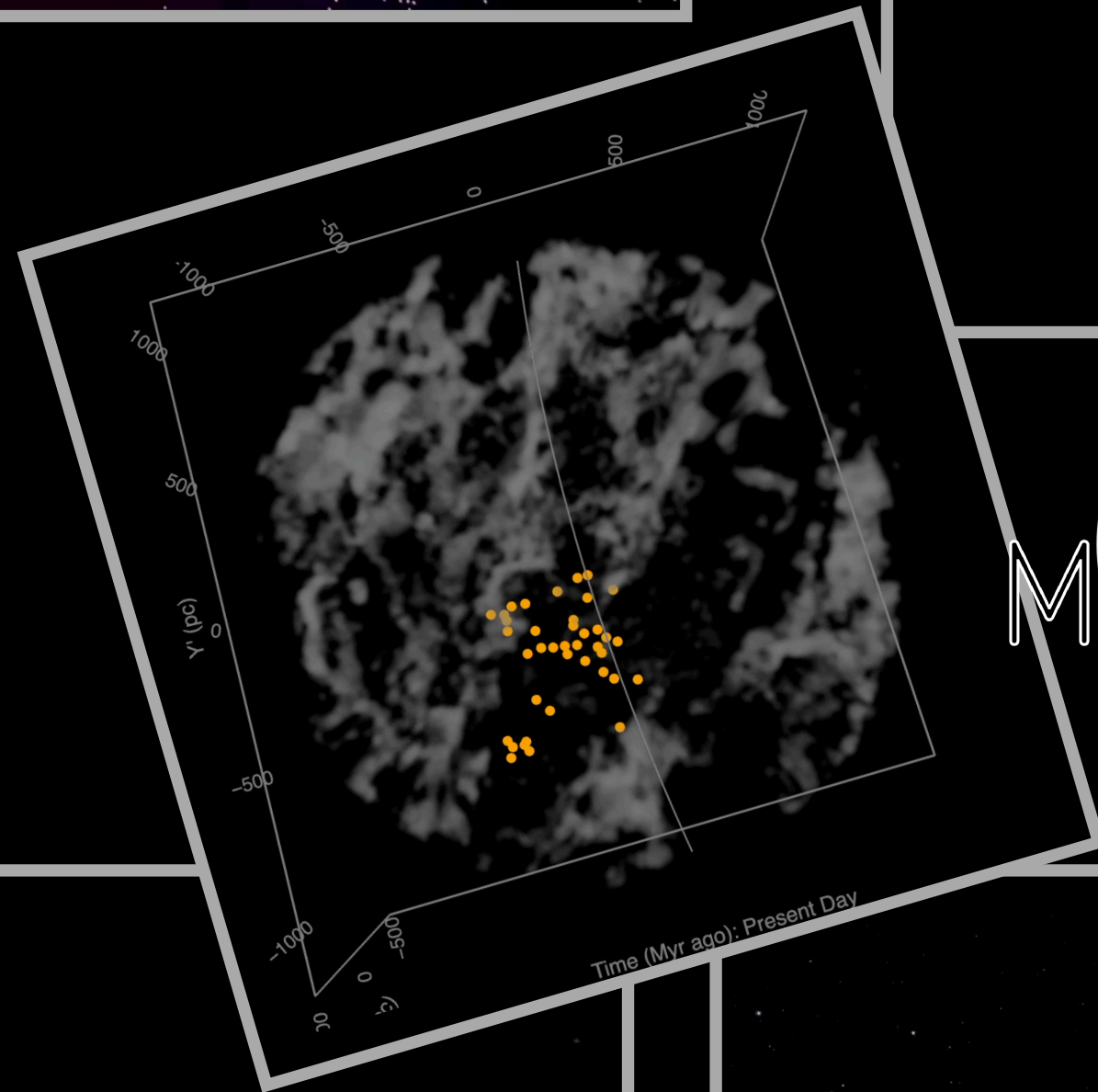
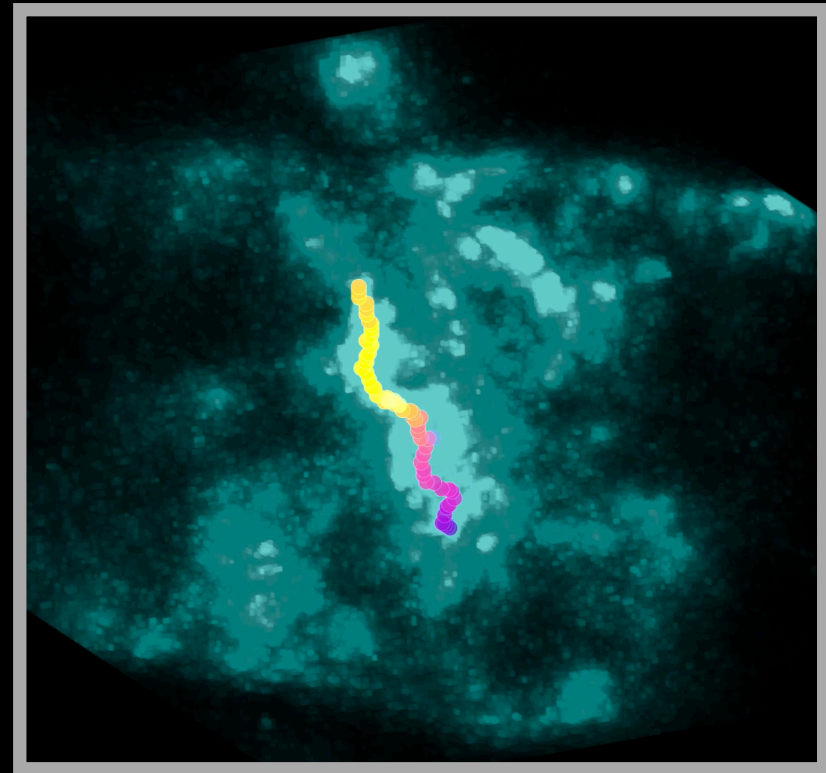
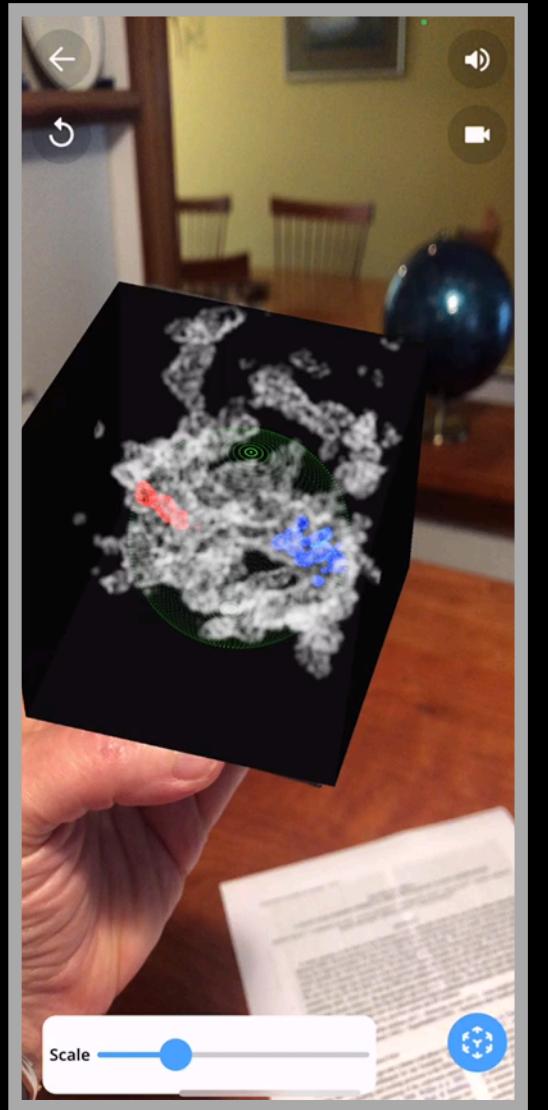
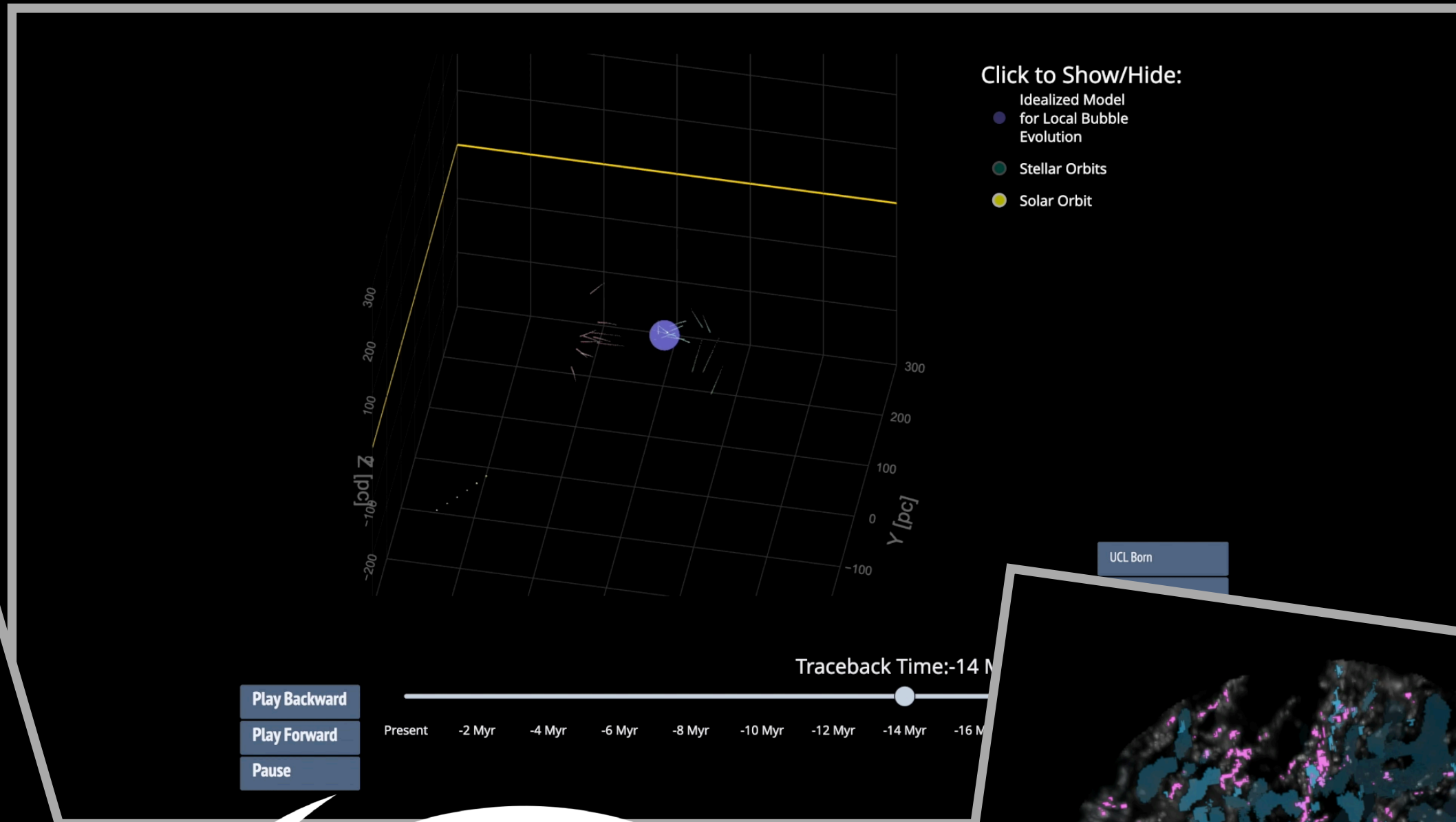
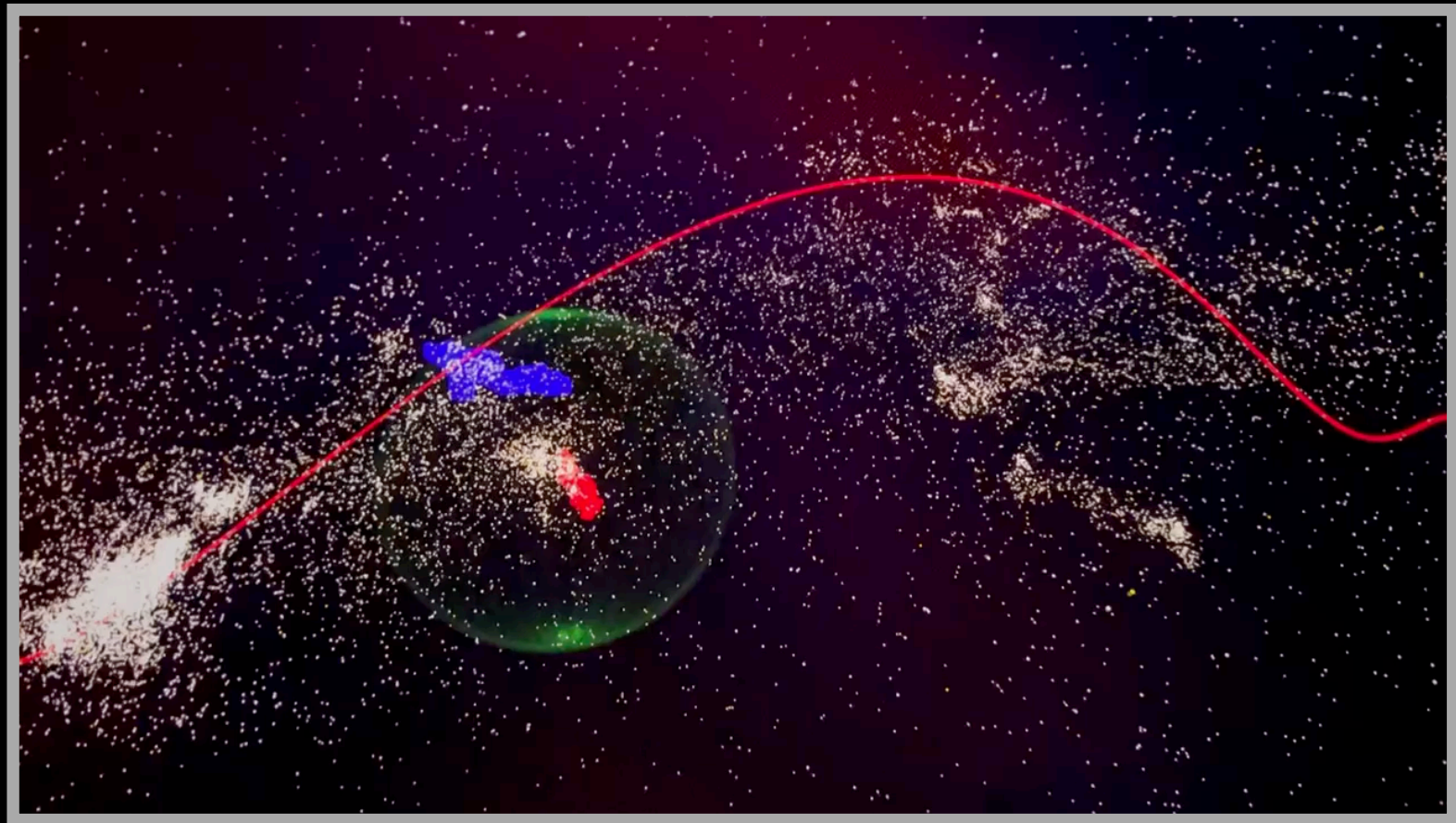


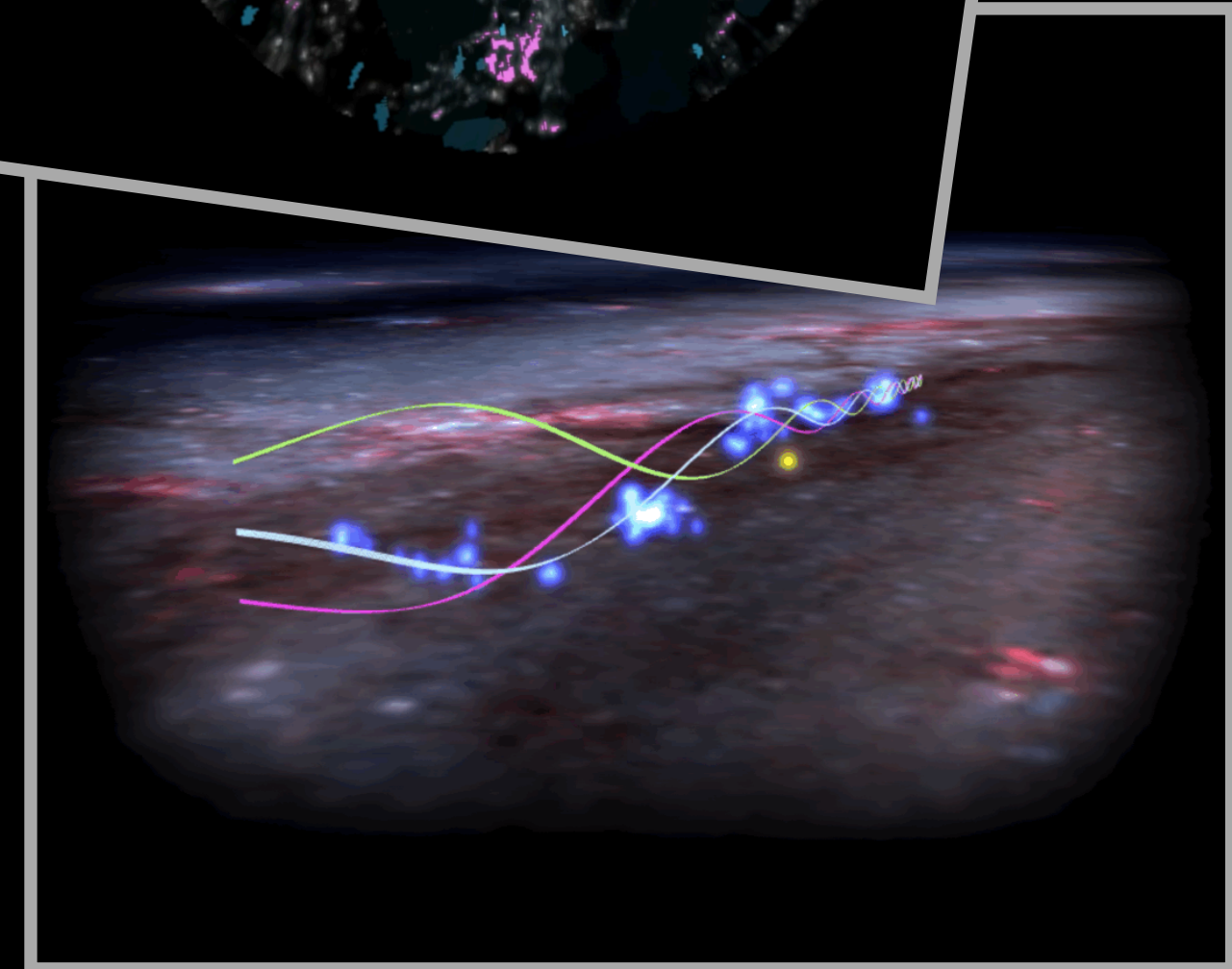
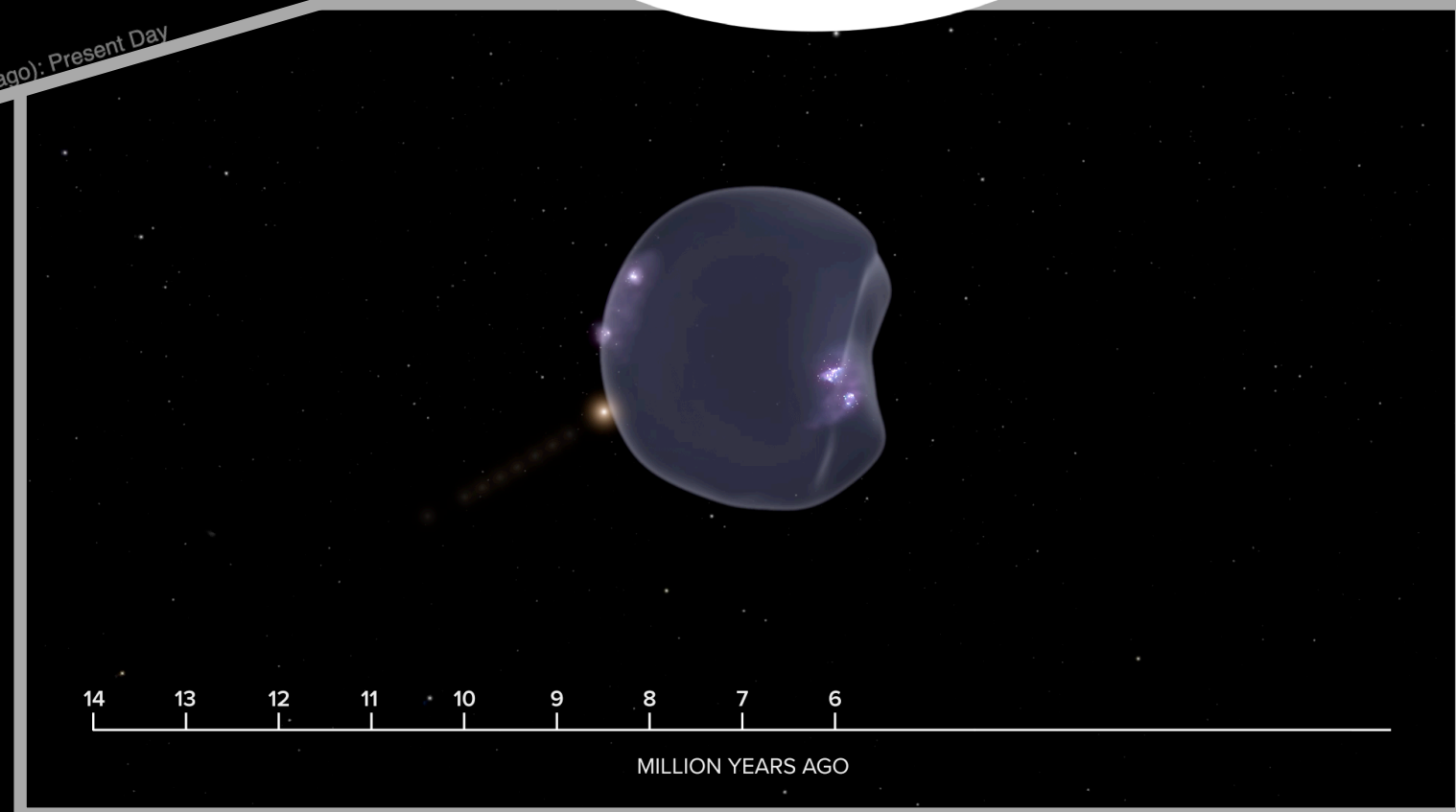
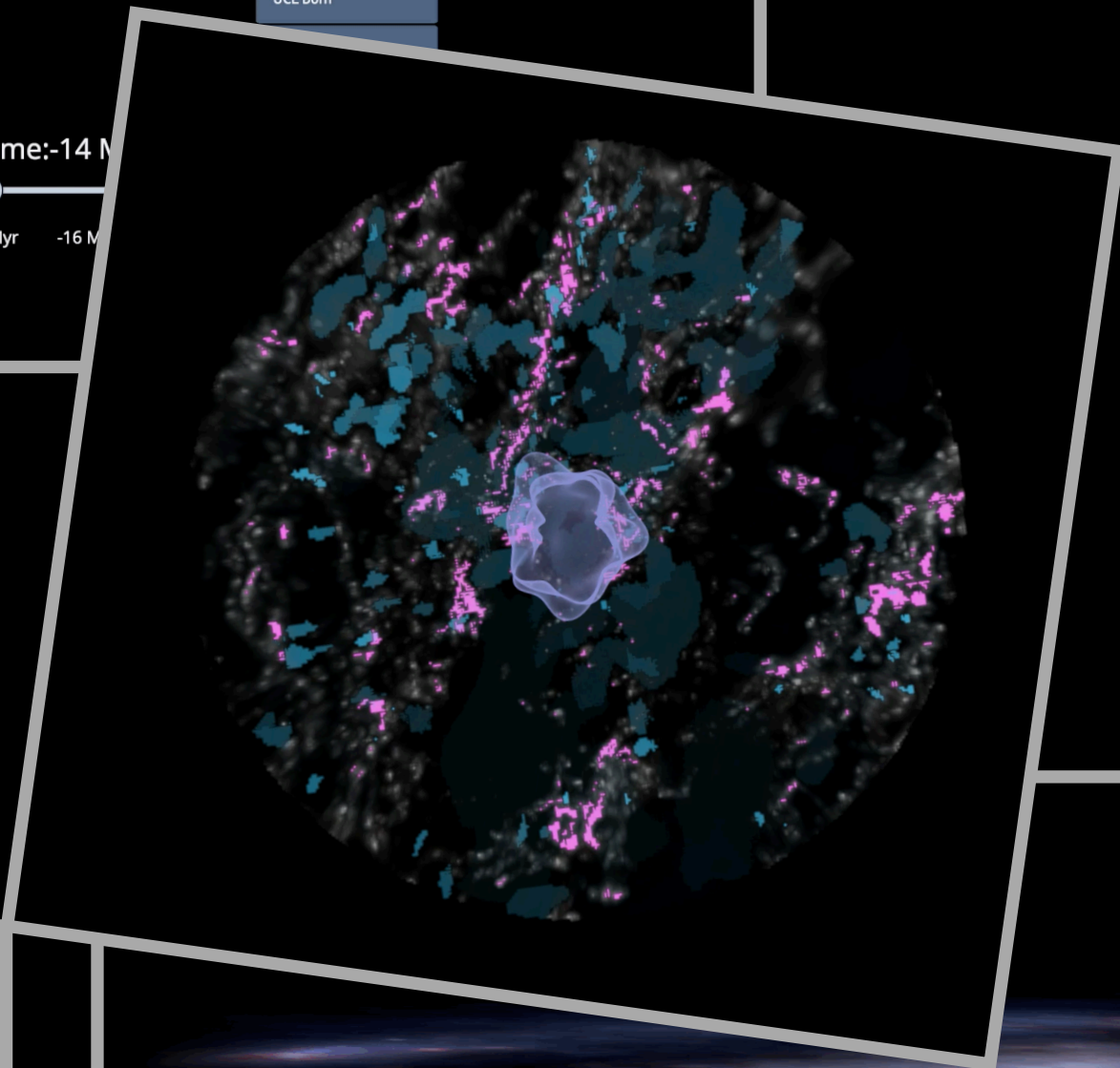
“Making a 3D Movie of the Star-Forming Milky Way I never thought I'd see”



AG, with Catherine Zucker, Center for Astrophysics | Harvard & Smithsonian; Jacqueline Faherty, American Museum of Natural History; Joao Alves, University of Vienna; Brian Abbott, American Museum of Natural History; Micah Acinapura, American Museum of Natural History; Robert Benjamin, University of Wisconsin, Whitewater; Gordian Edenhofer, Max Planck Institute for Astrophysics—> CfA; Carter Emmart, American Museum of Natural History; Douglas Finkbeiner, Center for Astrophysics | Harvard & Smithsonian; Ralf Konietzka, Center for Astrophysics | Harvard & Smithsonian; Theo O'Neill, Center for Astrophysics | Harvard & Smithsonian; Andrew Saydjari, Center for Astrophysics | Harvard & Smithsonian—> IAS; Robert Hurt, IPAC, and the Full MilkyWay3D.org Team, ++...see “Collaborators” at MilkyWay3D.org.

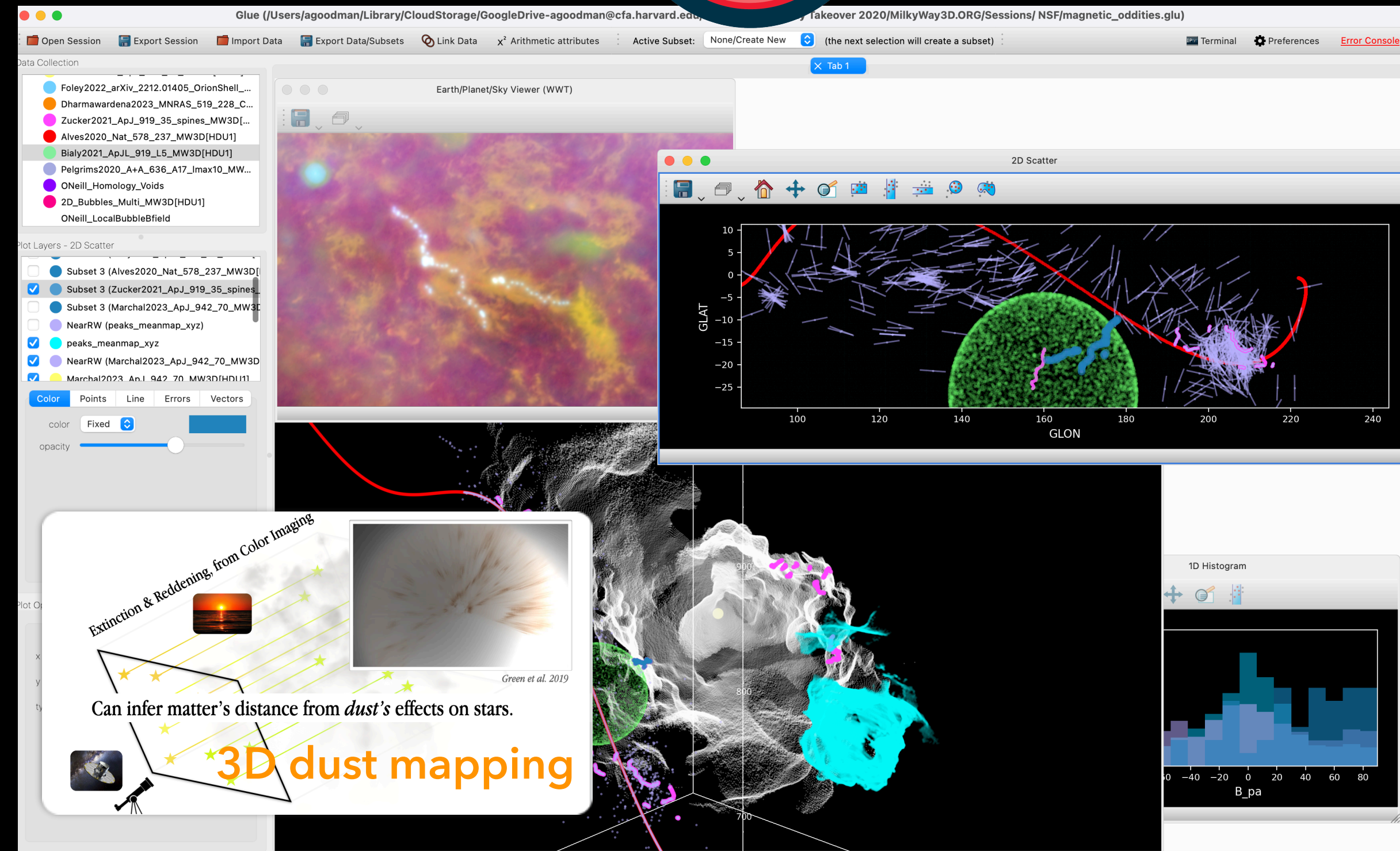
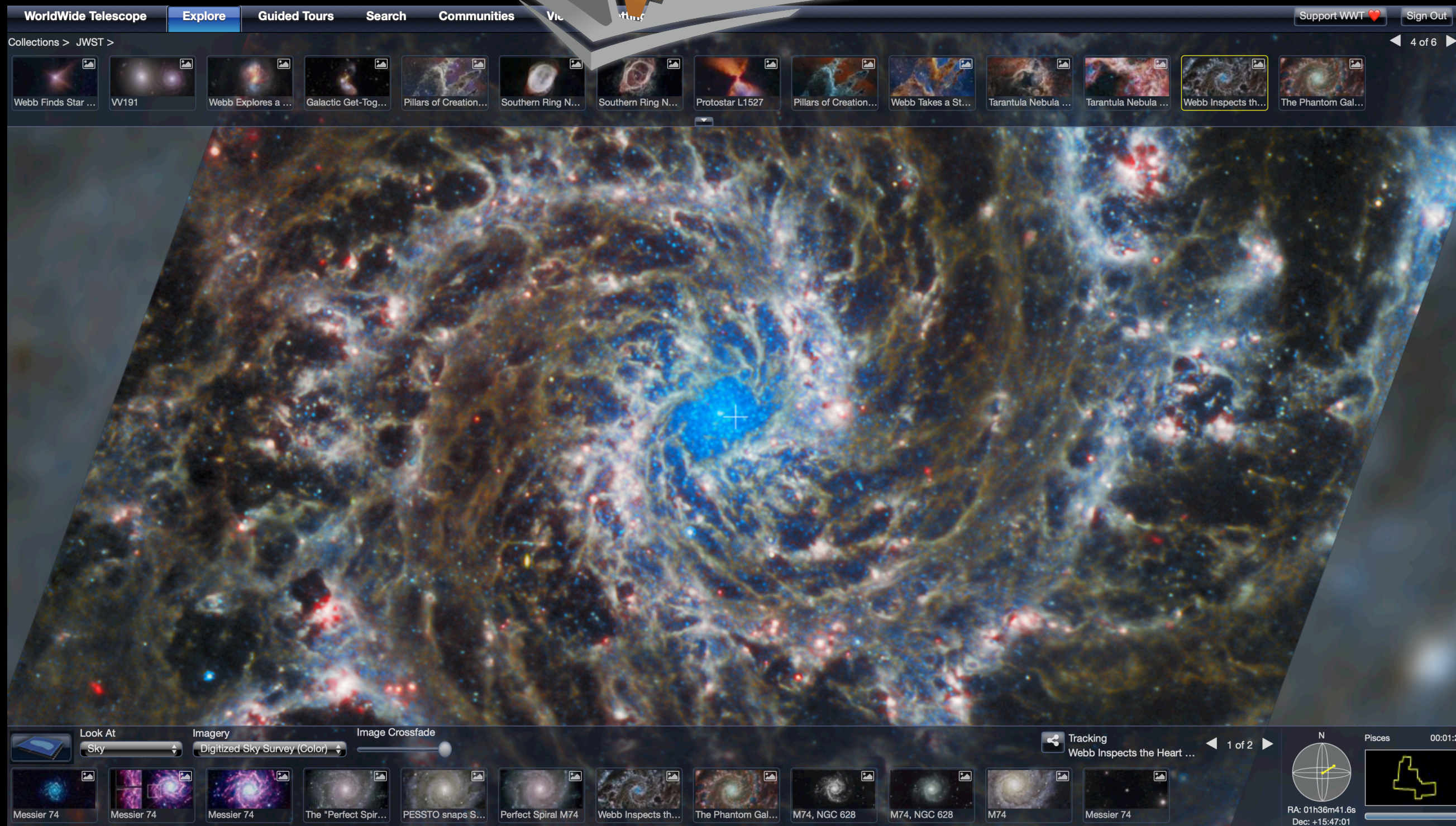
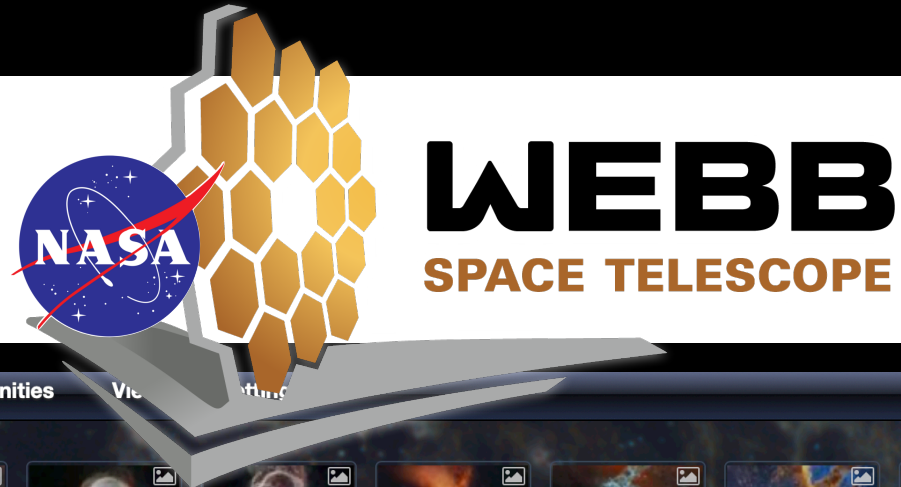


MILKYWAY3D.org



Zucker et al. 2021, Bialy et al. 2021; Zucker et al. 2022, Konietzka et al. 2024, O'Neill et al. 2024, Swiggum et al. 2024

unprecedented data

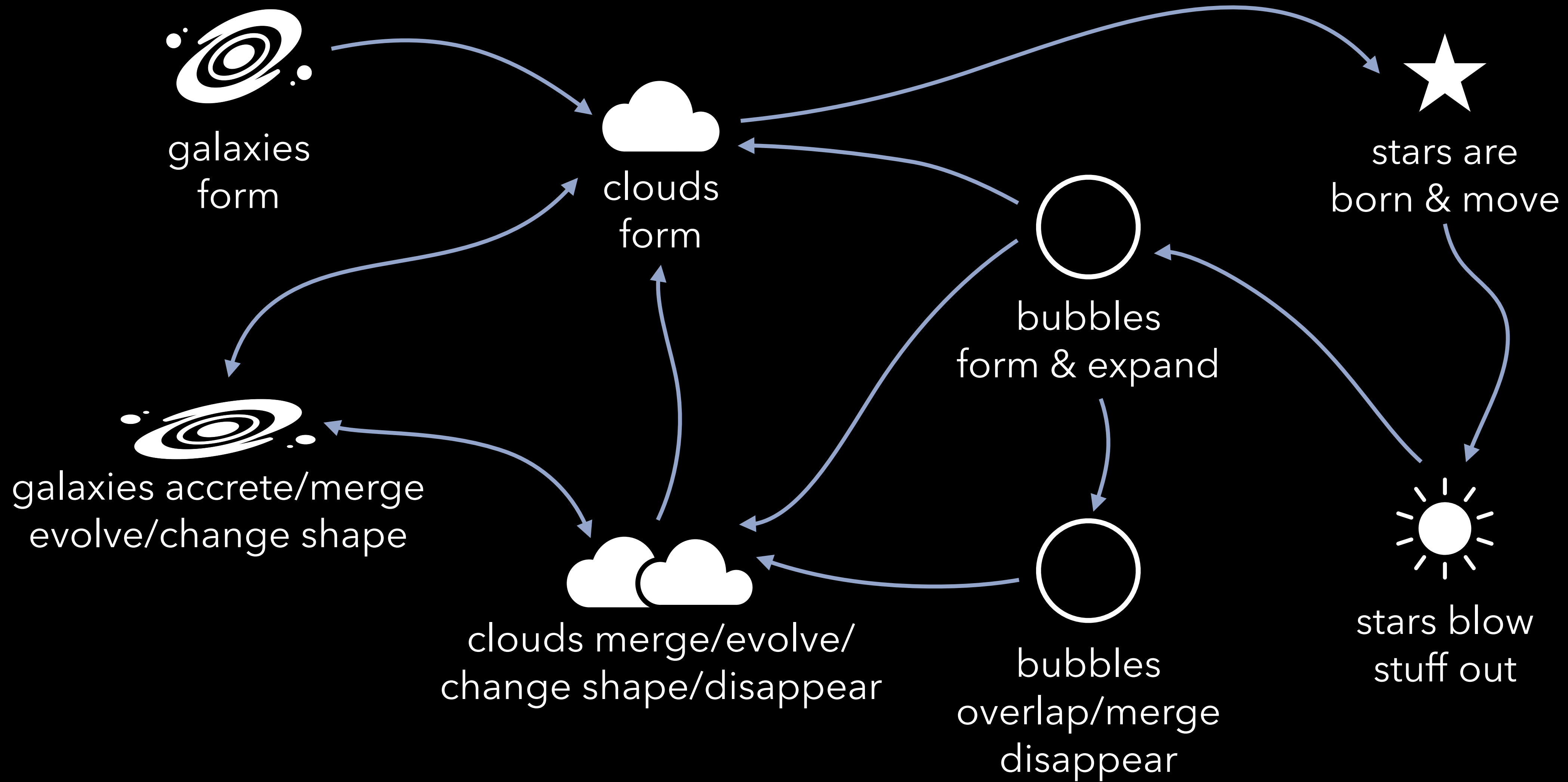


Extinction & Reddening from Color Imaging
Can infer matter's distance from *dust's* effects on stars.
3D dust mapping

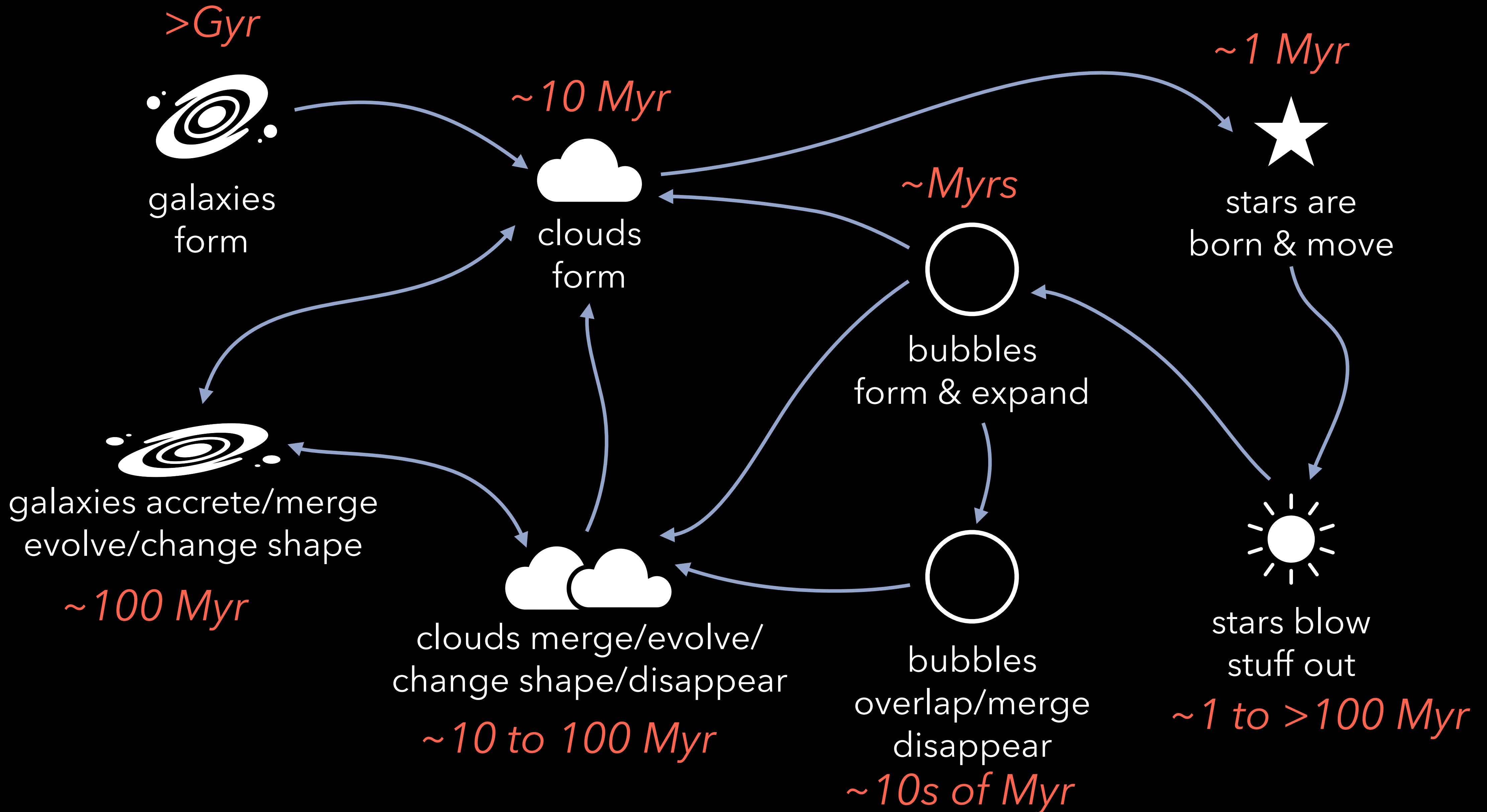


unprecedented software tools

“Everything, Everywhere, All at Once”



“Everything, Everywhere, All at Once”



An “Agent-based” Model for a Star’s Life in the Galactic ISM?

Much work, including my own, seeks to understand how stars form in galaxies, and how they interact with its ISM over time (e.g. via accretion/outflows, radiation, SNe, etc.)

Usually, a statistical approach is used, to look at a “region” over time & see what happens. How many stars, of what age, doing what, to that region.

NOW, though, using new observations of billions of stars, and the newest simulations, it has become possible to model the PATH of individual stars, as they form, and orbit the Milky Way.

So, we can create an “agent-based” model, where we track stars, one-at-a-time, in a Milky-Way-like galaxy, to monitor (and “see”!) what happens around them, from **100,000 year to 100Myr timescales.**

One early goal: “How do young stars leave home?” We know that stellar velocity dispersion increases from ~ 10 km/s for “young-ish” (~ 100 Myr-old) stars to >50 km/s for the oldest stars (>10 Gyr). BUT—we do NOT know **how VERY young stars go from ~ 1 km/s to 10 km/s, during the first Myr of their lives.** We should figure that out!

*And, yes,
we need
to “partner”
with AI*

ChatGPT 4o >

An **Agent-Based Model (ABM)** of a star moving through a galaxy's interstellar medium (ISM) would simulate the interaction between an individual star (agent) and the surrounding ISM, capturing how local physical processes influence the star's motion and environment. This type of model could help explore **stellar-ISM interactions**, including:

- **Bow shocks** and stellar wind interactions.
- **Gas accretion and stripping** affecting the star's surroundings.
- **Turbulent and magnetohydrodynamic (MHD) effects** in the ISM.
- **Galactic structure influences**, such as spiral arm dynamics.

Key Components of the Model

1. **Agents** – Stars moving through the ISM, each with properties like mass, velocity, wind strength, and magnetic field interaction.
2. **Environment** – The ISM, modeled as a dynamic medium with density variations, magnetic fields, turbulence, and temperature gradients.
3. **Rules & Behaviors**
 - Stars move under gravitational forces from the galaxy and interactions with local ISM structures.
 - High-velocity stars may create bow shocks.
 - Stellar winds may compress or stir the surrounding gas.
 - Local ISM properties (density, pressure, turbulence) affect the star's wake and potential gas accretion.

Potential Applications

- **Understanding runaway stars:** How fast-moving stars affect and interact with the ISM.
- **Bow shocks and stellar wind bubbles:** Studying shock structures around massive stars.
- **Impact on galactic structure:** How migrating stars contribute to turbulence and

+ 🌐 🔄 ↻ 4o



< Star Ism Abm ▾



```
1 from mesa import Agent, Model
2 from mesa.space import ContinuousSpace
3 from mesa.time import RandomActivation
4 import numpy as np
5 import matplotlib.pyplot as plt
6
7 class StarAgent(Agent):
8     def __init__(self, unique_id, model, pos, velocity, mass, wind_strength):
9         super().__init__(unique_id, model)
10        self.pos = np.array(pos)
11        self.velocity = np.array(velocity)
12        self.mass = mass
13        self.wind_strength = wind_strength
14
15    def move(self):
16        """Move the star through the ISM, affected by drag and
17        local density"""
18        local_density = self.model.get_ism_density(self.pos)
19        drag_force = -0.1 * local_density * self.velocity # Simulate drag
20        self.velocity += drag_force # Adjust velocity due to drag
21        self.pos += self.velocity # Update position
22
23    def step(self):
24        self.move()
25
26 class ISMModel(Model):
27     def __init__(self, width, height, num_stars):
28         self.space = ContinuousSpace(width, height, torus=False)
29         self.schedule = RandomActivation(self)
30         self.stars = []
31
32         # Initialize ISM density map (simple noise for turbulence)
33         self.ism_density = np.random.rand(width, height) * 0.5
34
35         # Create stars
36         for i in range(num_stars):
37             pos = np.random.rand(2) * [width, height]
38             velocity = (np.random.rand(2) - 0.5) * 2 # Random velocity
39             mass = np.random.uniform(1, 10)
40             wind_strength = np.random.uniform(0.1, 1.0)
41             star = StarAgent(i, self, pos, velocity, mass, wind_strength)
42             self.schedule.add(star)
43             self.stars.append(star)
44             self.space.place_agent(star, tuple(pos))
45
46     def get_ism_density(self, pos):
47         """Return ISM density at a given position, considering
48         local density variations"""
49         x, y = int(pos[0]), int(pos[1])
50         return self.ism_density[x][y]
```

[>]